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FIBER OPTIC TOW CABLE(U) ITT ELECTRO-OPTICAL PRODUCTS
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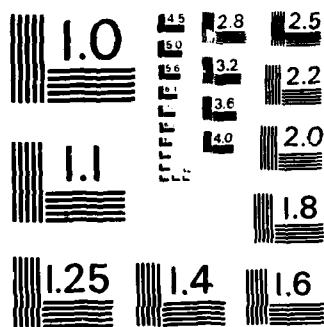
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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FIBER OPTIC TOW CABLE

FINAL REPORT

Contract N0014-82-C-2484

ITT Project 36062

Prepared for:

Nava Research Laboratories
Washington, D.C.

Prepared by:

ITT Electro-Optical Products Division
7635 Plantation Road, N.W.
Roanoke, Virginia 24019

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Approved by:


R. Coon
Program Manager

Approved by:


A. Asam
Senior Group Manager

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Date: December 20, 1983

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1.0 PROGRAM OVERVIEW

The contract was originally worded in September 1982, and was for the development and fabrication of two types of TOW cables, one of open channel design and one of loose tube design. The deliverables were a 450 meter armored section of each type and a 200 meter unarmored core of each type.

During the program it became evident that an additional design type (Interstitial Niche) should be fabricated and tested. As a result, in June 1983 the contract was modified to deliver two additional 450 meter sections of interstitial niche armored cables, one with five fibers and one with six fibers. The cable properties and drawings depicting the four designs finally chosen are in ^{this document} ~~Enclosure 1~~.

2.0 CONDUCT OF THE PROGRAM

To utilize the maximum expertise available, it was determined that two designs (open channel and 6-fiber interstitial niche) would be designed and that the cores would be fabricated at ITT EOPD, while the remaining two designs would be designed and fabricated by Rochester Corp. Fibers were provided by ITT EOPD and armoring was performed by Rochester Corp. Close coordination was maintained throughout the program with the NRL COTR. Formal and informal design reviews were held on a regular basis. In addition, the COTR witnessed virtually every major fabrication effort at both ITT EOPD and Rochester Corp.

Date: December 20, 1983

This program provided a great deal of information on four potential TOW cable designs. While not all designs were successful, the information learned will enable the Government to take the next logical development steps. The summary of optical test results are in Enclosure 2 and can be summarized as follows:

3.2 6-Fiber Interstitial Niche Design. Problems were encountered with this design during armoring with the core becoming deformed (Z kinked). Further evaluation would be required to determine why this design failed during armoring while a very similar design was successful.

3.4 Open Channel Design. This design did not provide satisfactory results during this program. Additional design effort would be required prior to implementing this approach.

SECRET

Date: December 20, 1983

ENCLOSURE 1
CABLE PROPERTIES AND DESIGNS

Date: December 20, 1983

OPTICAL FIBER PROPERTIES

TYPE: ITT, graded index, silica

SIZE: .050 mm core, .125 mm cladding

BUFFER JACKET: Hytrel/RTV to .500 mm nominal diameter

ATTENUATION: 3 to 4 dB/km at 830 nm wavelength

DISPERSION: <1 ns/km FWHM at 830 nm wavelength

STRENGTH: Prooftested to 2 % strain

5-FIBER INTERSTITIAL DESIGN

SUMMARY OF CABLE PROPERTIES

* CENTRAL CONDUCTOR

- Gauge: AWG #21
- Material: alloy 135 (Little Falls Alloy)
- Construction: 19 strands
- Insulation: polypropylene
- Jacket diameter: .160 (.063)

* PERIPHERAL CONDUCTORS

- Number: 5
- Gauge: AWG #18
- Material: alloy 135
- Construction: 19 strands
- Insulation: polypropylene
- Jacket diameter: .216 (.085)

* OPTICAL FIBERS

- As previously tabulated, but overjacketed to .076 (.030) with TRC product DATEX 52

* ASSEMBLY PROPERTIES

- Lay length: 7.72 (3.04)
- Conductor pitch diameter: .376 (.148)
- Conductor lay angle: 8.7 deg (RH)
- Conductor coverage: 98.8 %
- Fiber pitch diameter: .490 (.193)
- Fiber lay angle: 11.3 deg (RH)
- Fiber radius of curvature: 6.41 (2.52)
- Void filler: TRC product DATEX 47
- Binder tape: adhesive backed polyester (.75" X .002")
- Assembly diameter: .602 (.237)

* FINAL JACKET EXTRUSION

- Material: high density polyethylene
- Type of extrusion: pressure
- Mean diameter: .866 (.341)
- Standard deviation: .0021 (.00082)
- Number of diameter measurements: 60

Note: All dimensions are in units of cm (inches).

TUBE DESIGN

SUMMARY OF CABLE PROPERTIES

* CENTRAL STRAND STRENGTH MEMBER

- S-GLASS (glass-fiber, epoxy matrix)
(Air Logistics Corp)
- Measured diameter: .056 (.022)

* OPTICAL FIBERS

- As previously tabulated.

* FIBER ASSEMBLY

- Number of fibers: 6
- Fiber jacket diameter: .043 (.017)
- Lay length: 4.85 (1.91)
- Pitch diameter: .099 (.039)
- Lay angle: 3.67 deg (LH)
- Coverage: 87.4 %
- Fiber radius of curvature: 12.1 (4.76)
- Void filler: TRC proprietary

* EXTRUDED JACKET FOR FIBER ASSEMBLY

- Material: TRC product DATEX 52
- Type of extrusion: pressure
- Jacket diameter: .406 (.160)

* CONDUCTORS

- Gauge: AWG #22
- Material: alloy 135 (Little Falls Alloy)
- Construction: 7 strands .025 (.010) wire
- Insulation: polypropylene
- Jacket diameter: .140 (.055)

* CONDUCTOR ASSEMBLY

- Number of conductors: 11
- Lay length: 5.21 (2.05)
- Pitch diameter: .546 (.215)
- Lay angle: 18.3 deg (RH)
- Coverage: 95.6 %
- Void filler: TRC product DATEX 47
- Binder tape: polyester (1" X .003") with 40 % lap
- Assembly diameter: .701 (.276)

* FINAL JACKET EXTRUSION

- Material: high density polyethylene
- Type of extrusion: pressure
- Mean diameter: .869 (.342)
- Standard deviation: .0041 (.0016)
- Number of diameter measurements: 80

Note: All dimensions are in units of cm (inches).

Note: All dimensions in units of cm (inches).

6-FIBER INTERSTITIAL DESIGN

SUMMARY OF CABLE PROPERTIES

* CONDUCTORS

- Number: 7
- Gauge: AWG #22
- Material: alloy 135 (Little Falls Alloy)
- Construction: 7 strands .031 (.012) wire
- Insulation: polypropylene
- Jacket diameter: .183 (.071) central
.178 (.070) peripheral

* OPTICAL FIBERS

- As previously tabulated.

* ASSEMBLY

- Lay length: 7.14 (2.81)
- Conductor pitch diameter: .361 (.142)
- Conductor lay angle: 9.02 deg (RH)
- Coverage: >100 %
- Fiber pitch diameter: .467 (.184)
- Fiber lay angle: 11.6 deg (RH)
- Fiber radius of curvature: 5.76 (2.27)
- Void filler: ethyl vinyl acetate
(Solar Compounds Corp. product #3114)
- Binder tape: none used

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* FINAL JACKET EXTRUSION

- Material: high density polyethylene
- Type of extrusion: pressure
- Mean diameter: .861 (.339)
- Standard deviation: .0076 (.0030)
- Number of diameter measurements: 38

Note: All dimensions in units of cm (inches).

CHANNELED CORE DESIGN

SUMMARY OF CABLE PROPERTIES

* CONDUCTORS (type 1)

- Number: 2
- Assembly location: central and peripheral
- Gauge: AWG #22
- Material: silver-plated copper
- Construction: 19 strands .015 (.006) wire
- Insulation: polypropylene
- Jacket diameter: .114 (.045)

* CONDUCTORS (type 2)

- Number: 5
- Assembly location: peripheral
- Gauge: AWG #22
- Material: copper
- Construction: 7 strands .025 (.010) wire
- Insulation: polypropylene
- Jacket diameter: .124 (.049)

* FIBERS

- As previously tabulated.

* CHANNELED CORE

- Number of channels: 6
- Profile: continuous helix (LH)
- Material: high density polyethylene
- Channel dimensions: see drawing
- Channel lay length: 9.02 (3.55)
- Fiber pitch diameter: .587 (.231)
(at bottom of channel)
- Fiber lay angle: 11.6 deg (LH)
- Fiber radius of curvature: 7.32 (2.88)
- Void filler: ethyl vinyl acetate
(Solar Compounds Corp. product #3114)

Note: All dimensions in units of cm (inches).

SUMMARY OF ARMOR PROPERTIES

TRC CORES

* LAYER 1

- Number of wires: 26
- Wire size: .107 (.042)
- Wire type: SGIPS
- Lay length: 7.70 (3.03)
- Assembly diameter: 1.069 (.421)
- Mean core diameter: .869 (.342)
- Core diameter compression: 1.46 %
- Lay angle: 21.5 deg (RH)
- Preforming: 83 %
- Coverage: 98.8 %

* LAYER 2

- Number of wires: 32
- Wire size: .107 (.042)
- Wire type: SGIPS
- Lay length: 9.98 (3.93)
- Assembly diameter: 1.28 (.504)
- Core diameter compression: 1.75 %
- Lay angle: 20.3 deg (LH)
- Preforming: 78.0 %
- Coverage: 98.9 %

SUMMARY OF ARMOR PROPERTIES

6-FIBER INTERSTITIAL DESIGN

* LAYER 1

- Number of wires: 26
- Wire size: .107 (.042)
- Wire type: SGIPS
- Lay length: 8.64 (3.40)
- Assembly diameter: 1.052 (.414)
- Mean core diameter: .861 (.339)
- Core diameter compression: 2.6 %
- Lay angle: 19.0 deg (RH)
- Preforming: -----
- Coverage: 99.1 %

* LAYER 2

- Number of wires: 32
- Wire size: .107 (.042)
- Wire type: SGIPS
- Lay length: 10.52 (4.14)
- Assembly diameter: 1.262 (.497)
- Core diameter compression: 2.95 %
- Lay angle: 19.1 deg (LH)
- Preforming: -----
- Coverage: 99.6 %

Note: All dimensions in units of cm (inches).

SUMMARY OF ARMOR PROPERTIES

CHANNELED CORE DESIGN

* LAYER 1

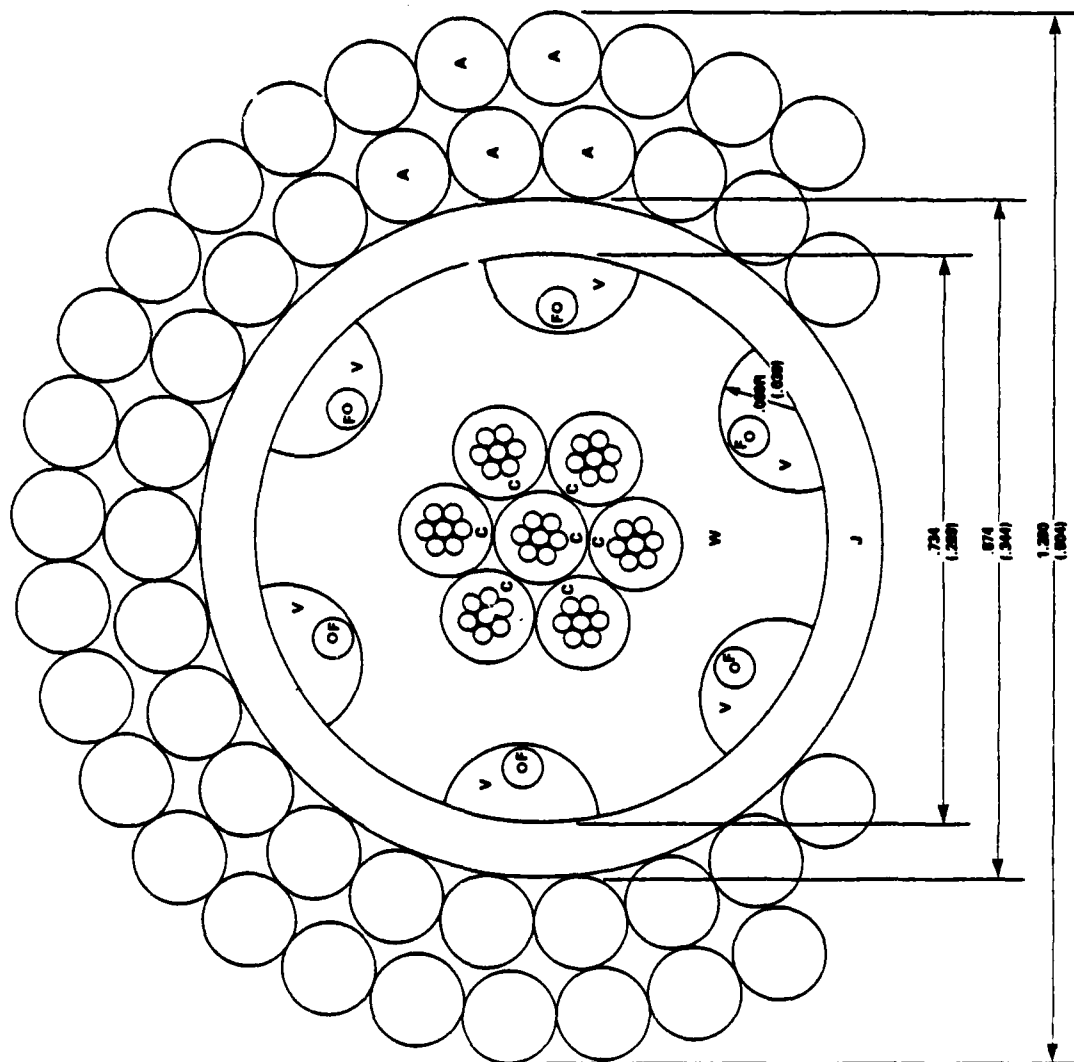
- Number of wires: 26
- Wire size: .107 (.042)
- Lay length: 8.92 (3.51)
- Assembly diameter: 1.062 (.418)
- Mean core diameter: .866 (.341)
- Core diameter compression: 2.05 %
- Lay angle: 18.6 deg (RH)
- Preforming: _____
- Coverage: 97.8 %

* LAYER 2

- Number of wires: 32
- Wire size: .107 (.042)
- Wire type: SGIPS
- Lay length: 10.46 (4.12)
- Assembly diameter: 1.268 (.499)
- Core diameter compression: 2.9 %
- Lay angle: 19.2 deg (LH)
- Preforming: _____
- Coverage: 99.3 %

Note: All dimensions in units of cm (inches).

CHANNELED CORE DESIGN



C: AWG #22 CONDUCTORS
INSULATED TO .122 (.048)

W: EXTRUDED CHANNELED CORE
WITH CONTINUOUS HELIX

F: OPTICAL FIBERS
.060 (.020) JACKET DIAMETER

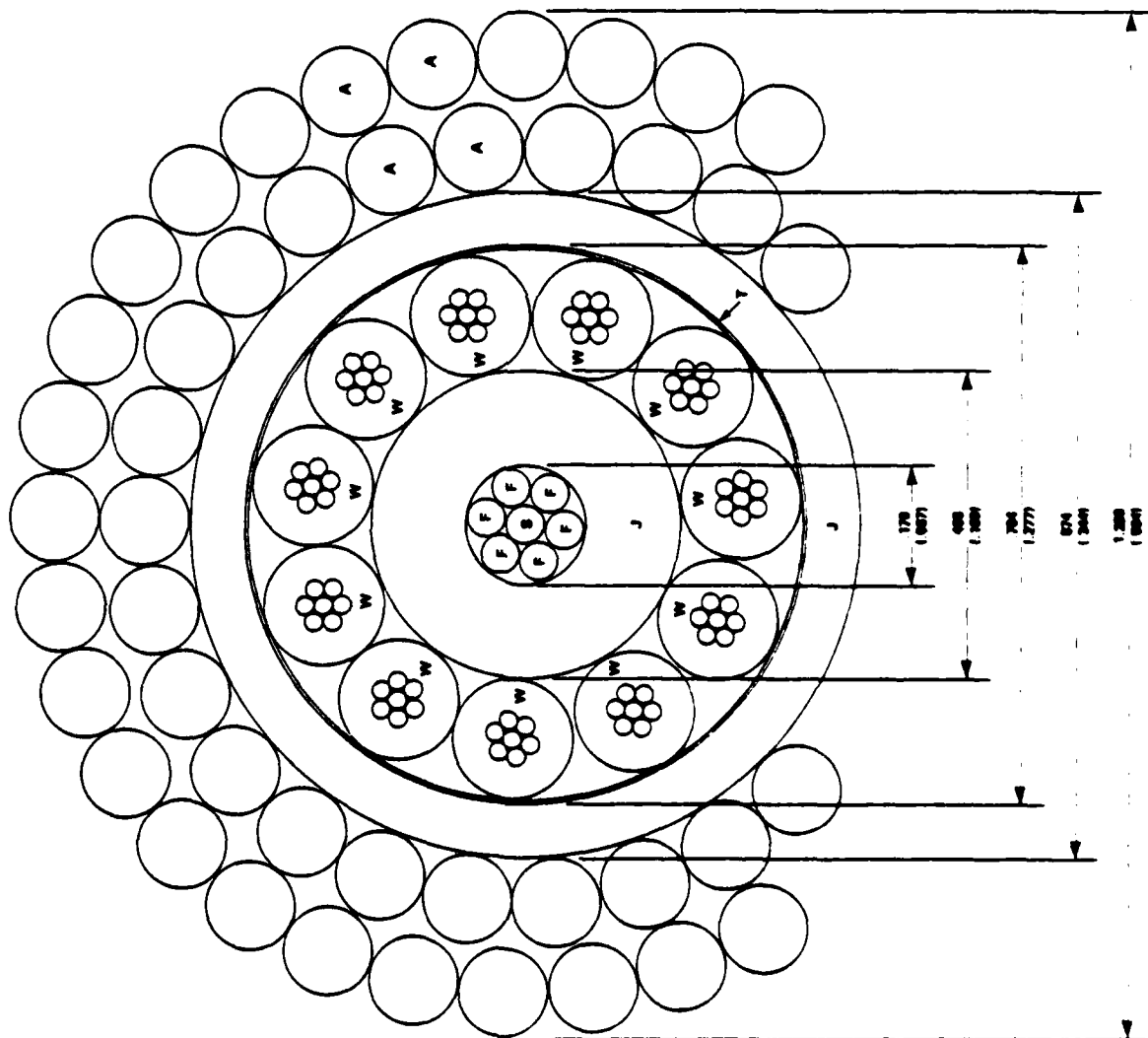
V: VOID FILLER

J: EXTRUDED JACKET (H.P.E.)

A: GIPS ARMOR WIRE (26/32)
.107 (.042) DIAMETER

NOTE: ALL DIMENSIONS IN CM (INCHES)

TUBE DESIGN



S: S-GLASS STRENGTH MEMBER

F: JACKETED OPTICAL FIBER

V: VOID FILLER

J: EXTRUDED JACKET (H.P.E.)

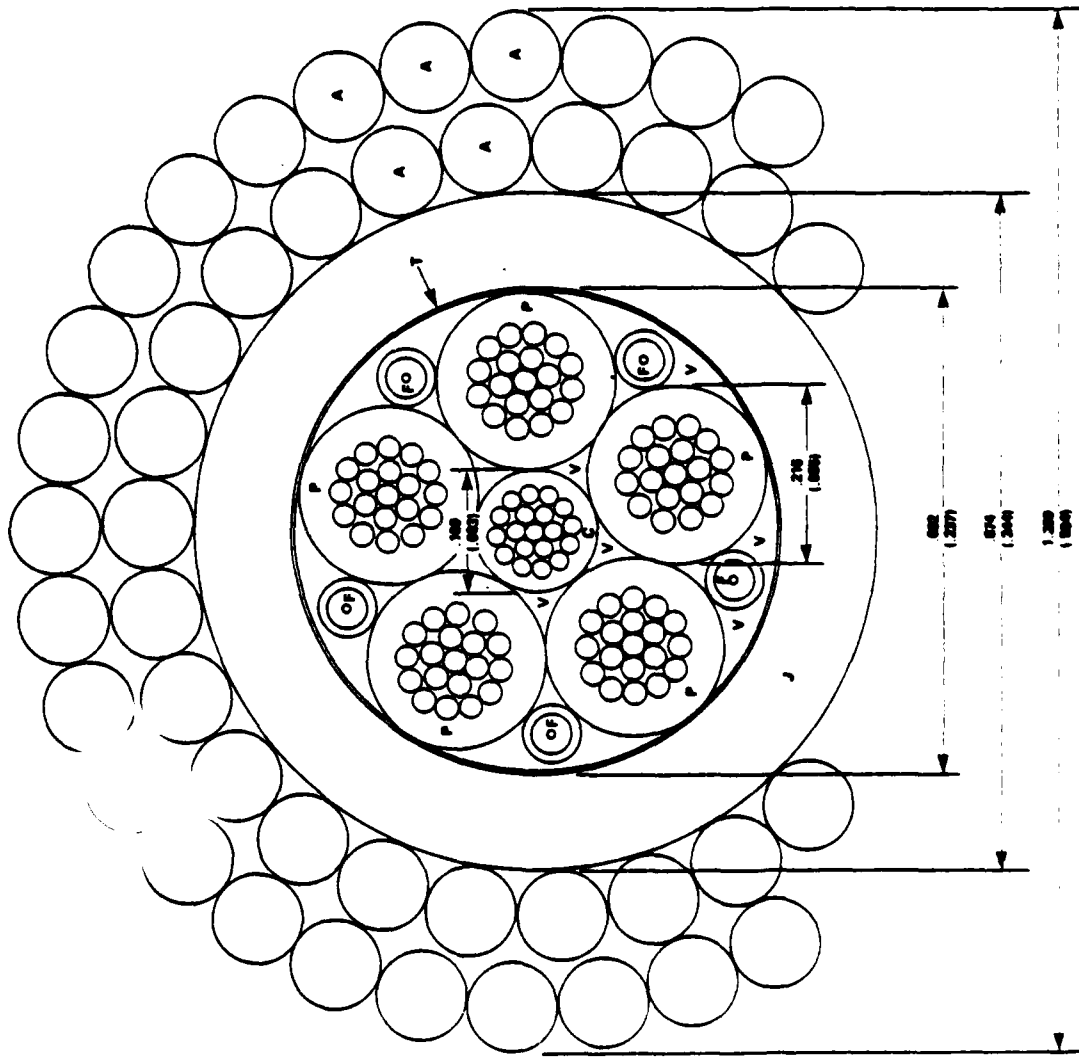
W: AWG #22 CONDUCTORS
INSULATED TO .140 (.055)

A: GIPS ARMOR WIRE (26/32)
.107 (.042) DIA.

T: POLYESTER TAPE WRAP

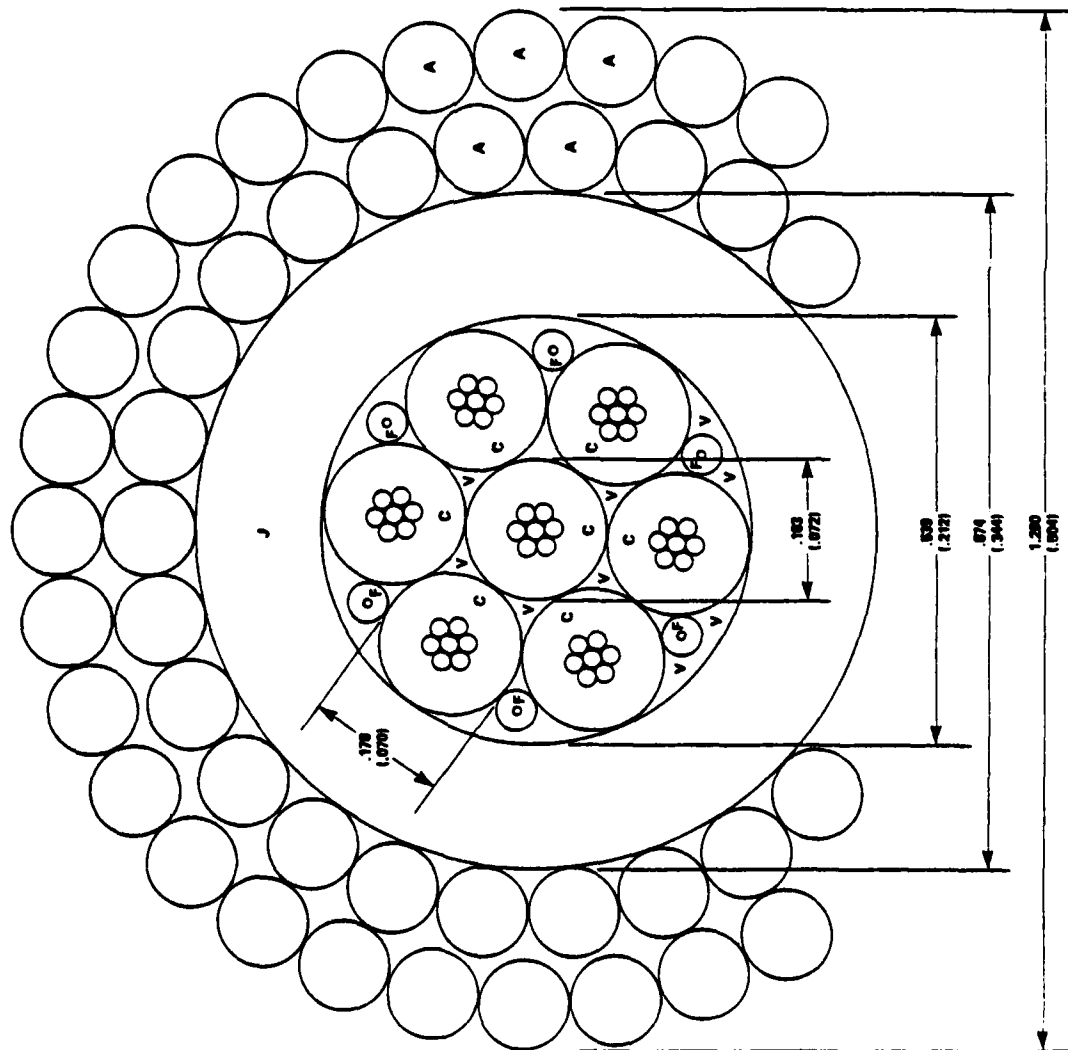
NOTE: ALL DIMENSIONS IN CM (INCHES)

5-FIBER INTERSTITIAL NICHE DESIGN



- C: AWG #21 CONDUCTOR
 - P: AWG #18 CONDUCTOR
 - F: OPTICAL FIBER OVERJACKETED TO .076 (.030)
 - V: VOID FILLER
 - T: POLYESTER TAPE WRAP
 - J: EXTRUDED JACKET (H.P.E.)
 - A: GIPS ARMOR WIRE (26/32) .107 (.042) DIAMETER
- NOTE: ALL DIMENSIONS IN CM (INCHES)

6-FIBER INTERSTITIAL NICHE DESIGN



C: AWG #22 CONDUCTOR

F: OPTICAL FIBER
.050 (.020) JACKET DIAMETER

V: VOID FILLER

J: EXTRUDED JACKET (H.P.E.)

A: GIPS ARMOR WIRE (28/32)
.107 (.042) DIAMETER

NOTE: ALL DIMENSIONS IN CM (INCHES)

ENCLOSURE 2

SUMMARY

TEST RESULTS

Date: December 20, 1983

5-FIBER INTERSTITIAL DESIGN

OPTICAL MEASUREMENTS DURING STAGES OF MANUFACTURING

Initial continuous length

ITT measurement: 3.5 dB/km

TRC measurement: 3.9 dB/km

After overjacketing to .076 cm (.030") diameter

TRC measurement: 3.5 dB/km

Numerical aperture: .23

Dispersion (nsec/km): .50 (50 %); .64 (10 %)

Bandwidth (MHz): 890 at 830 nm; 545 at 1300 nm

(attenuation in dB/km)

blu/grn blk/nat blu/blk nat/red red/grn

Assembled with
conductors, void filled,
and tape wrapped:

9.9	6.1	4.3	4.3	4.3
-----	-----	-----	-----	-----

After final jacket
extrusion and respooling:

4.5	4.4	3.9	4.4	4.4
-----	-----	-----	-----	-----

After armoring and
respooling:

4.2	5.5	4.4	4.9	4.7
-----	-----	-----	-----	-----

6-FIBER INTERSTITIAL DESIGN

OPTICAL MEASUREMENTS DURING STAGES OF MANUFACTURING

	gray	brown	green	orange	blue	clear
Num. aperture:	.23	.23	.23	.23	.22	.23
Dispersion (nsec/km):						
(50 %)	.77	.77	.77	.55	.80	.77
(10 %)	1.62	1.62	1.62	1.54	.35	1.62
Bandwidth (MHz):						
(830 nm)	667	667	667	680	632	677
(1300 nm)	658	658	658	648	1035	658
(attenuation in dB/km)						
Supplied fiber:	4.1	4.1	3.4	4.0	3.9	3.4
After assembly with conductors, void fill, and final jacket extrusion:	3.4	3.8	3.2	3.6	---	3.0
TRC measurement before armoring:	4.4	4.0	3.6	3.8	4.1	3.6
After armoring and respooling:	9.5	9.7	7.2	7.6	7.7	6.4

TUBE DESIGN

OPTICAL MEASUREMENTS
DURING STAGES OF MANUFACTURING

	white	gray	brown	purple	green	natural
Num. Aperture:	.26	.26	.22	---	.26	.26
Dispersion (nsec/km):						
(50 %)	.44	.92	.93	---	.37	.44
(10 %)	1.04	1.98	2.87	---	1.53	1.14
	(attenuation in dB/km)					
Supplied fibers:	3.6	3.7	2.9	---	3.9	3.6
TRC measurements:	4.3	5.5	3.0	---	3.9	3.2
Fibers assembled around S-glass central member, void filled, & jacketed by plastic extrusion:	4.5	4.4	4.5	5.3	3.8	4.9
Assembled with conduct- ors, void filled, and tape wrapped:	3.6	4.2	5.1	4.3	4.3	4.5
After final jacket extrusion:	3.9	4.2	4.4	3.9	4.0	4.3
After armoring and respooling:	3.5	3.5	4.4	4.6	4.1	4.1

CHANNELED CORE DESIGN

OPTICAL MEASUREMENTS
DURING STAGES OF MANUFACTURING

	slate	orange	green	brown	blue	natural
Num. aperture:	.23	.23	.23	.23	.22	.26
Dispersion:	---	---	---	---	---	---
Bandwidth (MHz-km):						
(830 nm)	780	---	---	780	---	533
(1300 nm)	440	---	---	440	---	683
(attenuation in dB/km)						
Supplied fibers:	3.7	4.0	4.0	3.8	3.9	3.3
Completed core assembly. ITT measurement:	3.8	4.4	5.5	3.5	4.4	4.9
Completed core assembly. TRC measurement:	3.9	5.2	5.2	5.7	5.7	4.8
After armoring and respooling.						
TRC measurement:	brk 71 m	27.1	21.5	11.7	brk 41 m	brk 12 m

5-FIBER INTERSTITIAL DESIGN

OPTICAL MEASUREMENTS DURING TENSION-CYCLE TESTING

		RED/GRN	NAT/RED	BLK/NAT	GRN/BLU	BLU/BLK
NUM. APERTURE		.23	.23	.23	.23	.23
FIBER LENGTH (METERS)		448	448	448	448	448
ARMORED ATTN (DB) (DB/KM)		2.1 4.7	2.2 4.9	2.5 5.5	1.9 4.2	2.0 4.4
CYCLE	LOAD (lbs)					
0	1000	2.0 4.5/km	2.2 4.9/km	2.9 6.5/km	2.2 4.9/km	2.4 5.4/km
1	5000	2.1 [0.7]	2.3 [0.7]	2.6 [-2.0]	2.7 [3.3]	2.4 [0.0]
7	5000	2.1 [0.7]	2.6 [2.7]	2.6 [-2.0]	2.6 [2.7]	1.9 [-3.3]
20	5000	2.0 [0.0]	2.3 [0.7]	2.4 [-3.3]	2.9 [4.7]	1.9 [-3.3]
21	7500	2.2 [1.3]	2.3 [0.7]	2.5 [-2.7]	2.1 [-0.7]	1.9 [-3.3]
30	7500	2.2 [1.3]	2.3 [0.7]	2.5 [-2.7]	2.1 [-0.7]	1.9 [-3.3]
40	7500	2.4 [2.7]	2.2 [0.0]	2.6 [-2.0]	2.1 [-0.7]	2.0 [-2.7]
AFTER 24 HRS ZERO TENSION		2.1 4.7/km	2.0 4.5/km	2.4 5.4/km	2.1 4.7/km	2.0 4.5/km

[] indicates change in attenuation in dB/km based on 150 m of cable stressed.

Other numbers indicate the total measured attenuation in dB or dB/km

6-FIBER INTERSTITIAL DESIGN
OPTICAL MEASUREMENTS
DURING TENSION-CYCLE TESTING

		GREEN	BLUE	BROWN	ORANGE	GRAY	NATURAL
NUM. APERTURE		.23	.22	.23	.23	.23	.23
FIBER LENGTH (METERS)		483	483	483	483	483	483
ARMORED ATTN (DB) (DB/KM)		3.5 7.2/km	3.7 7.7/km	4.7 9.7/km	3.7 7.6/km	4.6 9.5/km	3.1 6.4/km
CYCLE	LOAD (lbs)						
0	1000	4.8 9.9/km	4.8 9.9/km	4.6 9.5/km	3.9 8.1/km	4.8 9.9/km	3.9 8.1/km
1	5000	6.5 [11.]	5.9 [7.3]	5.6 [6.7]	8.5 [31.]	5.3 [3.3]	3.8 [-0.7]
5	5000	6.9 [14.]	6.0 [8.0]	4.9 [2.0]	6.4 [17.]	3.9 [-6.0]	3.3 [-4.0]
10	5000	6.1 [8.7]	3.2 [-11.]	4.4 [-1.3]	4.7 [5.3]	4.0 [-5.3]	4.0 [0.7]
20	5000	6.2 [9.3]	3.3 [-10.]	6.1 [10.]	3.6 [-2.0]	4.0 [-5.3]	3.5 [-2.7]
25	7500	5.4 [4.0]	3.4 [-9.3]	4.2 [-2.7]	3.8 [-0.7]	3.8 [-6.7]	3.5 [-2.7]
32	7500	5.9 [7.3]	3.5 [-8.7]	6.2 [11.]	4.1 [1.3]	3.8 [-6.7]	3.2 [-4.7]
40	7500	4.9 [0.7]	3.3 [-10.]	4.4 [-1.3]	3.6 [-2.0]	4.1 [-4.7]	3.0 [-6.0]
AFTER 24 HRS ZERO TENSION		4.5 10./KM	3.5 7.8/KM	6.3 20./KM	4.3 9.6/KM	4.4 9.8/KM	3.1 6.9/KM

[] indicates change in attenuation in dB/km based on 150 m of cable stressed.

Other numbers indicate the total measured attenuation in dB or dB/km.

This core was deformed (Z-kinked) during armoring. OTDR traces show many discontinuities.

TUBE DESIGN

OPTICAL MEASUREMENTS DURING TENSION-CYCLE TESTING

		WHITE	GREEN	NATURAL	GRAY	BROWN	VIOLET
NUM. APERTURE		.26	.26	.26	.26	.22	---
FIBER LENGTH (METERS)		452	435	452	452	452	452
ARMORED ATTN (DB) (DB/KM)		1.6 3.5	1.8 4.1	1.9 4.2	1.6 3.5	2.0 4.4	2.1 4.6
CYCLE	LOAD (lbs)						
0	0	1.7 3.8/km	1.9 4.4/km	2.2 4.9/km	1.7 3.8/km	2.3 5.1/km	1.8 4.0/km
1	5000	2.0 [2.0]	* *	2.7 [3.3]	2.2 [3.3]	5.5 [21.]	3.0 [8.0]
5	5000	1.8 [0.7]	* *	2.6 [2.7]	2.1 [2.0]	5.5 [21.]	3.1 [8.7]
20	5000	1.8 [0.7]	* *	2.6 [2.7]	2.1 [2.0]	5.1 [19.]	3.0 [8.0]
21	7500	1.8 [0.7]	* *	2.6 [2.7]	2.1 [2.0]	4.8 [17.]	2.7 [6.0]
30	7500	1.8 [0.7]	* *	2.5 [2.0]	2.2 [3.3]	5.1 [19.]	2.9 [7.3]
40	7500	2.0 [2.0]	2.3 [2.7]	2.5 [2.0]	2.1 [2.0]	4.7 [16.]	2.7 [6.0]
AFTER 24 HRS ZERO TENSION		1.6 3.6/km	1.7 3.9/km	2.5 5.6/km	1.7 3.8/km	2.0 4.5/km	1.9 4.2/km

[] indicates change in attenuation in dB/km based on 150 m of cable stressed.

Other numbers indicate the total measured attenuation in dB or dB/km.

* Green fiber broken near measurement end. Two data values measured from other end of cable.

CHANNELED CORE DESIGN

OPTICAL MEASUREMENTS
DURING TENSION-CYCLE TESTING

		BROWN	GREEN	ORANGE
FIBER LENGTH (METERS)		344	344	344
NUM. APERTURE		.23	.23	.23
ARMORED ATTN. (DB) (DB/KM)		4.1 12.	7.5 22.	9.5 27.
CYCLE	LOAD (lbs)			
0	1400	3.7 11/km	4.7 14/km	7.6 22/km
1	5000	3.0 [-4.7]	4.2 [-3.3]	6.2 [-9.3]
10	5000	2.9 [-5.3]	4.2 [-3.3]	6.0 [-11.]
21	7500	2.6 [-7.3]	4.7 [0.0]	4.2 [-23.]
30	7500	2.6 [-7.3]	3.8 [-6.0]	5.2 [-16.]
40	7500	2.1 [-11.]	4.2 [-3.3]	5.2 [-16.]
AFTER 24 HRS ZERO TENSION		3.2 9.3/km	5.0 15./km	7.2 21./km

[] indicates change in attenuation in db/km based on 150 m of cable stressed.

Other numbers indicate the total measured attenuation in dB or dB/km.

The brown, green, and orange fibers have multiple glitches in the OTDR traces. The other three fibers are broken.

END

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